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Field notes on *Craugastor azueroensis* (Savage, 1975) (Amphibia: Anura: Craugastoridae)

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In 1975, Savage described *Eleutherodactylus azueroensis* from "Panama: Provincia de los Santos: N slope Cerro Cambutal, 480 m." Currently, this species is placed in the genus *Craugastor* and assigned to the *C. punctariolus* species series within the *C. rugulosus* species group (Campbell and Savage, 2000; Savage, 2002; Hedges, Duellman and Heinicke, 2008). Since its original description, little has been published on this species. Solís et al. (2004a) and Stuart et al. (2008) summarized what little we know on the geographic distribution, natural history, and conservation status of this species which is endemic to the Azuero Peninsula. *Craugastor azueroensis* is listed as "Endangered" on the IUCN Red List because "its Extent of Occurrence is less than 5,000 km^2, its distribution is severely fragmented, and there is continuing decline in the extent and quality of its habitat" (Solís et al., 2004a).

We collected voucher specimens that have been deposited in the collection of the Senckenberg Forschungsinstitut Frankfurt (SMF) and in the Museo Herpetológico de Chiriquí (MHCH), the herpetological collection of the Universidad Autónoma de Chiriquí, Davíd, Chiriquí, Panama. Specimens listed below with GK field numbers will be deposited at MHCH. Species identification was carried out employing the keys, figures, and descriptions provided by Savage (1975), Campbell and Savage (2000), and Köhler (2011). The capitalized colours and colour codes (the latter in parentheses) are those of Smithe (1975–1981). Coordinates and elevation were recorded using Garmin GPS receivers with built-in altimeters. All coordinates are in decimal degrees, WGS 1984 datum. Abbreviation used: SVL = snout-vent length. We took skin swabs from the belly and ventral surface of the thigh from seven individuals of *C. azueroensis*. These swabs were sent to a lab (Hessisches Landeslabor Gießen) for testing for the presence of the pathogenic fungus *Batrachochytrium dendrobatidis* Longcore, Pessier and Nichols, 1999 DNA using a PCR assay.

From 31 January to 2 February 2011, three persons (GK, AB, and AC) visited Parque Nacional Cerro Hoya, Azuero Peninsula, Panama. On 31 January 2011 at 5:00 h, we started at Finca of Juancho Velasquez (7.35234°N, 80.78671°W; 145 m) and reached our campsite at 900 masl (7.29032°N, 80.78653°W) at 16:00 h. From 18:40 to 21:00 h, GK and AC sampled a 350 m transect along one of the several small rocky streams in the vicinity of camp. There was some drizzling rain during most of the night hike. *Craugastor azueroensis* appeared to be relatively abundant in the portion of this stream surveyed, and in the time between 19:00 h and 20:40 h, we counted a total of 12 individuals of *C. azueroensis* on a 100 m section of the transect (Table 1), 7 adults (SVL: 40–60 mm) and 5 juveniles (SVL: ≤ 25 mm). Most individuals were encountered on the upper surface of rocks and logs within the streambed less than one metre from the water. AB, who sampled a different stream between 19:00 h to 22:30 h, walked a distance of around 350 m and observed six *C. azueroensis*; four adults (SVL: 40–60 mm) and two juveniles (SVL: ≤ 25 mm).

From 14-15 March 2011, GK and AC visited the Reserva Forestal Montuoso, Azuero Peninsula, Panama. During our night walk, we observed four adult individuals of *Craugastor azueroensis*, all at the edges of streams (Fig. 1a). At 21:00 h, we encountered a *Bothrops asper* (Garman, 1883) (now SMF 93661; SVL: 745 mm) at the edge of a small lagoon (Fig. 1b), which was holding a *C. azueroensis* (now SMF 92004) in its mouth. The snake had seized the frog by the posterior part of its body. When caught, the snake released the

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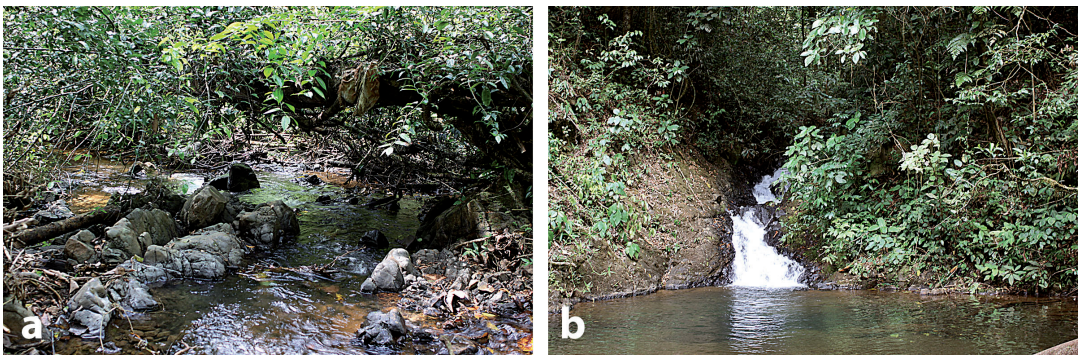

Figure 1. Habitat of *Craugastor azueroensis* in the Reserva Forestal Montuoso (a) a stream near the lagoon; (b) the lagoon mentioned in the text.

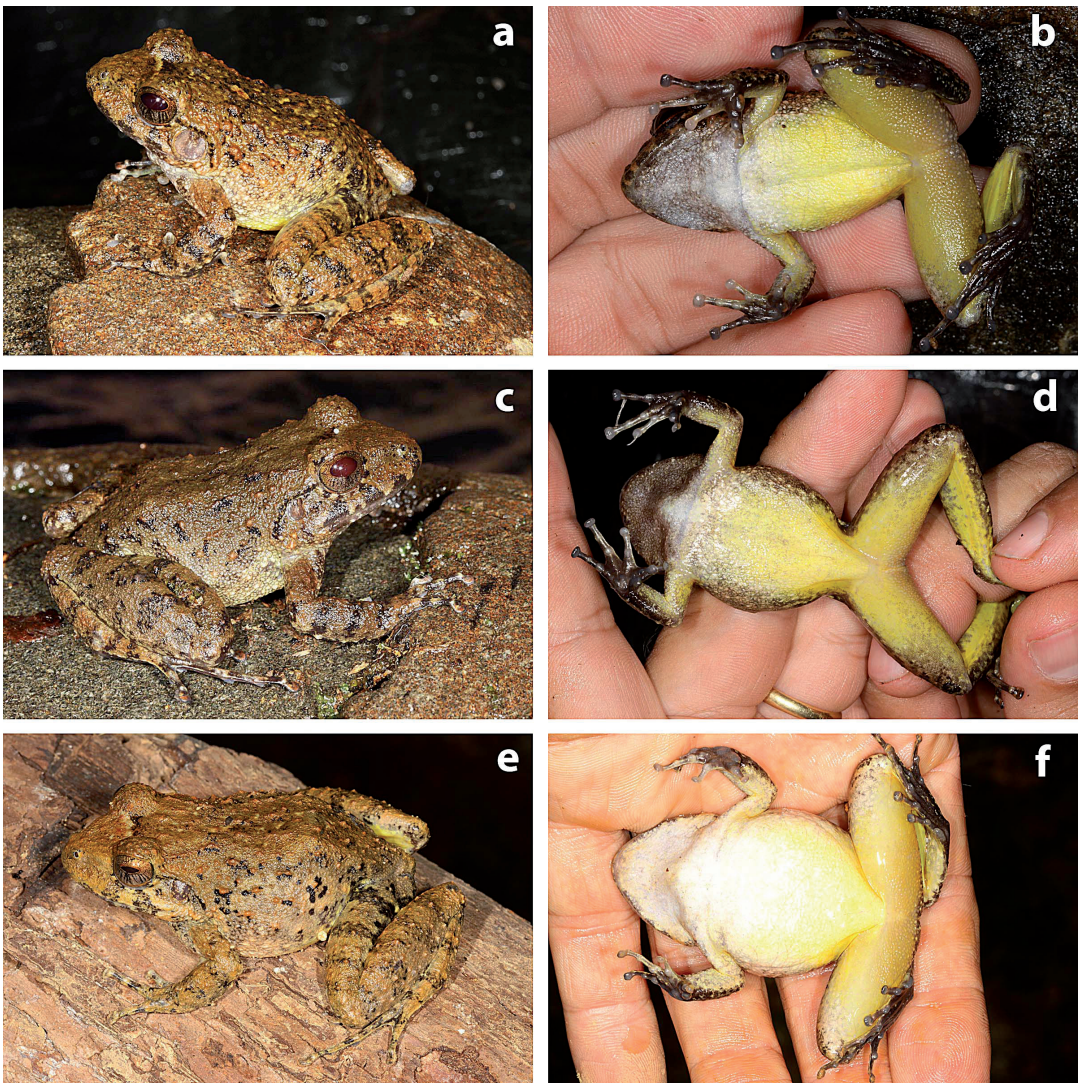

Figure 2. *Craugastor azueroensis* in life. (a, b) SMF 92003, male from Cerro Hoya. (c, d) GK-3086, female from Cerro Hoya. (e, f) SMF 92005, female from Montuoso. See text for details.

Table 1. Findings of *Craugastor azueroensis* along a 100 m section of a 350 m transect at Parque Nacional Cerro Hoya, Azuero Peninsula, Panama

Time	Lat.	Lon.	Observation	Location
19:00	7.28985°N,	80.78605°W	1 juvenile	On ground
19:08	7.28977°N,	80.78613°W	1 adult	On rock
19:25	7.28976°N,	80.78619°W	1 juvenile	On rock
19:40	7.28971°N,	80.78623°W	1 adult	In hollow log, 150 cm above ground
20:00	7.28966°N,	80.78634°W	1 juvenile	On log in debris of stream
20:12	7.28968°N,	80.78636°W	1 juvenile	On rock
20:13	7.28967°N,	80.78638°W	1 adult	On log, 140 cm above ground
20:34	7.28923°N,	80.78621°W	4 adults, 1 juvenile	4 on rocks, 1 in a tree hole, 150 cm above ground
Total: 1:34 h	**Total distance: approx. 100 m**		**Total: 12 Individuals**	

frog from its fangs. The frog was already dead and had two large puncture wounds, one in each groin region. In addition to *C. azueroensis*, the stream-breeding tree frog *Smilisca sila* Duellman and Trueb, 1966 was also present in the lagoon in high abundance.

All skin swabs (of five individuals from Cerro Hoya and of two individuals from Montuoso) tested negative for the presence of *Batrachochytrium dendrobatidis* DNA (Eisenberg pers. comm. 14 April 2011).

At Cerro Hoya, we collected four specimens (GK-3064, 3086, SMF 92002-03), and at Montuoso two specimens (SMF 92004-05). All specimens agree well with the descriptions given by Savage (1975) and Campbell and Savage (2000) in terms of external morphology.

The colouration in life of an adult male (SMF 92003; Figures 2a,b) from Cerro Hoya was recorded as follows: Dorsum Verona Brown (223B) suffused with Sepia (119) middorsally; dorsal surfaces of forelegs and hind legs Raw Umber (123) with Jet Black (89) spots and Raw Umber (223) bars; posterior thigh Raw Umber (223) with Yellow Ocher (123C) flecks; venter Olive Yellow (52), suffused with Sulphur Yellow (157) grading into dirty white on chest; throat Army Brown (219B) with a dirty white midgular stripe and fine dirty white stipples; ventral surfaces of forelegs and hind legs Olive Yellow (45); undersides of feet Burnt Umber (22); iris Antique Brown (37).

The colouration in life of an adult female from Cerro Hoya (GK-3086; Figures 2c,d) was recorded as follows: Dorsum Ground Cinnamon (239) with Sepia (119) blotches and Tawny Olive (223D) tubercles and ridges; dorsal surfaces of forelegs and hind legs Raw Umber (123) with Raw Umber (223) bars; posterior thigh Raw Umber (223) with Yellow Ocher (123C) flecks; venter Olive Yellow (45), grading into dirty white on chest; throat Drab (27) with an indistinct dirty white midgular stripe and diffuse dirty white speckles; ventral surfaces of thigh Olive Yellow (45) with a suggestion of Buff-Yellow (53), that of shank Spectrum Yellow (53), and that of feet Fuscous (21); iris Antique Brown (37).

The colouration in life of an adult female (SMF 92005; Figures 2e,f) from Montuoso was recorded as follows: Dorsum Raw Umber (123) with Flesh Ocher (132D) and Sepia (119) flecks and tubercles; dorsal surfaces of forelegs and hind legs Raw Umber (123) with Sepia (119) bars; posterior thigh Raw Umber (223) with Straw Yellow (56) flecks (Fig. 3); venter Spectrum Yellow (55), grading into dirty white on midbelly and chest; throat dirty white with a suggestion of Brownish Olive (29); ventral surfaces of thigh Sulphur Yellow (157), that of shank Spectrum Yellow (55), and that of feet Dusky Brown (19); iris Tawny Olive (223D).

Among terrestrial breeding Neotropical frogs, the representatives of the *Craugastor rugulosus* species group are known to be very susceptible to chytridiomycosis (Lips, 1999; Campbell and Savage, 2000; McCranie and Wilson, 2002; Lips et al., 2004, 2006; Ryan, Lips and Eichholz, 2008; Ryan et al., 2010). Available data suggest that nearly all species in this group have experienced severe population declines

throughout Central America in the past 20 years (Ryan, Lips and Eichholz, 2008; Ryan et al., 2010). Seven of the eight species known to occur in Panama have declined drastically, and all eight species of this group in neighbouring Costa Rica have disappeared throughout most of the country (IUCN, 2011). Some surviving populations of *C. ranoides* were discovered in 2003 in lowland tropical dry forest on the Santa Elena Peninsula in north-western Costa Rica, whereas it has disappeared from the entire rest of its distribution range in that country (Puschendorf et al., 2005; Zumbado-Ulate, Puschendorf and Chavarría, 2007). Although *Batrachochytrium dentrobatidis* has been detected on *C. ranoides* in low concentrations at this site (Zumbado-Ulate pers. comm., 2012), recent data suggest that the Santa Elena population remains stable so far (Zumbado-Ulate, Puschendorf and Chavarría, 2007; Zumbado-Ulate et al., 2011). Puschendorf et al. (2005) hypothesized that the higher air and water temperature at this site, together with a prolonged dry season of six months, might allow protection from the pathogenic fungus, which grows best at lower temperatures and in humid climates (Piotrowski, Annis and Longcore, 2004; Andre, Parker and Briggs 2008).

In contrast, the populations of *Craugastor azueroensis* were found at much higher elevations than the population of *C. ranoides*, where the prevailing climate is much cooler and wetter. So far, little is known about the transmission dynamics of the amphibian chytrid fungus. Most likely, infection within and between different amphibian life stages and environment-to-amphibian transmission via water or moist soil are the most important ways of chytrid transmission in and between wild amphibian populations (Rachowicz and Vredenburg, 2004; Johnson and Speare, 2005; Lips et al., 2006; Rachowicz and Briggs, 2007). This explains the wave like spread of the disease in a predictable pattern along the central mountain ranges of Costa Rica and Panama. Infected frogs can readily migrate between different stream systems, thereby possibly acting as carriers of the pathogen; once the fungus has reached a new stream system, the pathogen can spread. As hypothesized by Lips et al. (2008), dry and hot lowlands might slow down the spread of chytrid, as they represent a dispersal barrier for both infected frogs and the fungus itself. The northern limit of the distribution area of *C. azueroensis* is separated from the central mountain range by approximately 100 km of hot and dry lowlands

Figure 3. Posterior surface of thigh in *Craugastor azueroensis* (SMF 92005).

that might prevent chytrid transmission. Also, there is generally little human travel in this direction, due mainly to the poor infrastructure in the south-western portion of the Azuero Peninsula. Additionally, the mountains on the Azuero Peninsula, as well as the mountains on the Santa Elena Peninsula, form hydrographical systems separated from the drainages of the central mountain range that precludes pathogen access by tadpole migration or drifting zoospores in water networks. The fact that both sites possess separated water systems and are surrounded by dry lowlands seems to be more important than high temperature alone, as demonstrated by the severe decline of *C. taurus* on the hot (but wet) Osa Peninsula and the surroundings of the Golfo Dulce in Costa Rica (Solís et al., 2004b). Another site that might form a natural refuge from *B. dentrobatidis* is the Cerro Azul mountain range on the hot and dry Nicoya Peninsula, where only scant monitoring work on amphibians has been conducted to date (Laurencio, 2009). However, *C. azueroensis* is listed as "Endangered" by on the IUCN Red List, primarily because of the restricted distribution area and the continuous decline of suitable habitat. During the 20th century, deforestation on the Azuero Peninsula caused great changes in the vegetation composition (Heckadon Moreno, 2009). Thus, endangered species such as *Pyrrhura eisenmanni* (Azuero Parakeet), *Ara ambiguus* (Great Green Macaw) and *C. azueroensis* have been suffering from habitat reduction (Angehr, 2003; Solís et al., 2004). Nowadays, these species require specific conservation strategies to survive; predominantly expansion of existing protected areas, demarcation of new protected areas, and comprehensive management plans for protected areas, as well as year-round surveillance by personnel to prevent deforestation and illegal hunting. In the particular case of *C. azueroensis*, long term studies such as monitoring programmes are needed to evaluate its population status.

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